DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES SPACE FORCE

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MEMORANDUM FOR SEE DISTRIBUTION

FROM: HQ USSF/VCSO
2020 United States Space Force Pentagon
Washington, DC 20330-2000

SUBJECT: United States Space Force Long-Term Science and Technology Challenges

1. The purpose of this memo is to identify Science and Technology (S&T) challenges the United States Space Force (USSF) must overcome in the next 10 to 35 years in order to continue deterring and defeating aggression in protection of US national interests in space.

2. The USSF's June 2020 Space Capstone Publication (SCP), *Spacepower*, is the first articulation of an independent theory of spacepower in support of US National Security Strategy and National Defense Strategy. In response to the guiding principles and core competencies in *Spacepower*, the USSF is developing an overarching force design. The USSF's S&T process provides an orderly way to analyze the required operational capabilities associated with this design, determine supporting technical needs, and prioritize the basic and applied scientific research necessary to develop and transition those technologies. At the same time, the S&T process allows for new scientific and technological breakthroughs with the potential to radically transform USSF operational capabilities. The primary role of the USSF S&T community is to drive innovation by identifying enabling basic and applied science, to foresee adversary advances impacting space capabilities, and to forecast asymmetric advantages enabled by new scientific breakthroughs.

3. The following long-term S&T challenges are intended to be non-prescriptive, neither exclusive nor exhaustive, and to illustrate broad focus areas to guide scientific research by the Air Force Research Laboratory (AFRL), the Defense Advanced Research Projects Agency (DARPA), other Department of Defense (DOD) and US Government laboratories, academic institutions, industry and international partners:

a. **Improving freedom of action in, from, and to the space domain.** Technologies that ensure our own freedom of action in space and the ability to deny our adversaries the same by enabling full-spectrum space domain awareness (SDA), force application in near-Earth and cislunar space, and the ability to fight through a complex, rapidly-evolving, multi-domain conflict while maintaining a state of chaos for an adversary, including: automated and autonomous systems; data analytics (DA), artificial intelligence (AI) and machine learning (ML); human-machine teaming for automated and remotely piloted systems; swarms of systems; evasive mechanisms; new and agile signal waveforms; improved cryptography methods and delivery; advanced computing, to include quantum computing, science, and algorithms; cloud communications for combat environment; improved spatial and temporal detection of threats and targets; attribution; predictive and cognitive electronic warfare; and trusted data sources.

b. **Improving survivability and resilience of space systems and architectures.** Technologies that ensure availability or recovery of capabilities during a multi-domain conflict, including: interoperability, resilience-by-design, nontraditional and zero-trust architectures; robust, self-healing, and non-fragile technologies; secure, agile, distributed, and autonomously reconfigurable communications and sensing subsystems (e.g., multi-band and ultra-wideband cognitive radios, software-defined networks, and photonic devices); defense, deception, and evasion in all domains; high maneuverability and cluster maneuvering; specific emitter identification; secure-in-space networks; personal identification and security authentication; timing solutions; radiation-hardened electronics; space layer flight management software and processing; and new electromagnetic or other technologies for transmitting communications and satellite commands unimpeded and undetected.

c. **Digital engineering (DE) and model based systems engineering (MBSE).** Technologies that enable secure, agile, and rapid development, prototyping, testing and deployment of software and hardware, including: increased system agility, responsiveness, and cyber resiliency; agile, integrated, cross-disciplinary tools for advanced information capture and sharing; applications of DE and MBSE in system of system integration, architecture, capability, and system design and development; additive and advanced manufacturing; fully networked battle management systems; predictive maintenance; accurate, timely, networked, and interoperable modeling and simulations; cloud computing in multi-level security environments; digital twins and modular open architectures common to digital twins and physical systems; visualization capabilities; and modeling dynamic events and autonomous decisions in multi-actor scenarios and threat environments.

d. **Increasing Responsible Artificial Intelligence, Machine Learning and Autonomy**. Technologies that enhance capability development, operations, mission assurance, data standards and collection, threat analysis, decision making, and system reaction, including: complex systems-of-systems composed of hardware, software, networks, and human-machine interfaces that are capable of self-optimization, self-configuration, self-diagnosis, and intelligent support of humans; autonomous, human-enhanced, or human-in-the-loop decision making; immutable data availability at the lowest classification level possible; seamless integration, transport, and storage of data at different classification levels; intelligent ecosystems; location detection; augmented reality-enhanced decision making; authentication and fraud/intrusion/threat detection and characterization; smart sensors; data visualization; interwoven cloud, fog, edge and cognitive computing; data triage and extraction of knowledge; and modeling of potential unintended consequences of AI system evolution.

e. **Improving space access, mobility, and logistics.** Technologies that expand capabilities in space, in traditional low Earth orbit (LEO), medium Earth orbit (MEO), and geostationary (GEO) regimes, but also highly elliptical orbit (HEO), beyond GEO (xGEO) and extending to Lunar and cislunar space, including: new spacelift technologies for rapid, flexible, and affordable deployment of space assets; in-space assembly; space-based manufacturing; additive and other advanced manufacturing techniques; servicing and repair; refueling for maneuver without regret; on-orbit depots; in-situ resource harvesting and utilization; space debris removal; autonomous robotic systems; standards for satellite servicing and debris mitigation; materiel storage and mobility in and through space; alternative satellite power sources; improved ground segment antennas, power systems, and security; easily deployable, short-term replacement capabilities for traditional essential space capabilities; and high-impulse, high-thrust, and/or long-duration propulsion technologies such as nuclear and hybrid propulsion.

f. **Enhancement and integration of existing services from and through an expanded space domain.** Technologies to evolve and revolutionize operating capability, lower lifecycle costs through alternative architectures, enhance space command and control, and expand the operational domain to and beyond cislunar space, including: ubiquitous assured positioning, navigation and timing; SDA; intelligence, surveillance and reconnaissance including ground and air moving target indications; missile warning, missile tracking; nuclear detonation detection; and space and terrestrial weather; search and rescue; space commerce defense; seamless integration of space with air, land, sea, and cyber operations; enhanced multi-phenomenology sensors; simultaneous observation of targets from multiple sensors with AI-supported fusion for joint all-domain command and control; nanotechnology; novel utilization of electromagnetic spectrum communications (e.g. optical in addition to radio frequency); quantum physics phenomenology for high-performance computing, communications, and sensing; edge computing; and big data analytics.

4. The USSF Chief Technology and Innovation Officer (CTIO) will lead incorporation of this guidance into USSF S&T activities.

DAVID D. THOMPSON
General, USSF
Vice Chief of Space Operations

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